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April 1992
Working Paper, No. 94

**The University of California
Transportation Center**

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Experiments With a Dynamic Microsimulation Model System**

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FORECASTING THE IMPACT OF SOCIODEMOGRAPHIC CHANGES ON TRAVEL DEMAND: EXPERIMENTS WITH A DYNAMIC MICROSIMULATION MODEL SYSTEM

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INTRODUCTION

Travel demand analysis and forecasting have developed rapidly over the past decade and are now entering a new "dynamic era" characterized by the recognition that time is an indispensable dimension of travel demand models (for overviews on the subject see Kitamura, 1990, and Pas, 1990). This paper addresses the development of new forecasting methods that explicitly account for this dynamic character of travel demand. The new approach, Microanalytic Integrated Demographic Accounting System (MIDAS), attempts to combine dynamic models of travel behavior with sociodemographic and economic microanalytic simulation. The strengths of this model system are: 1) the internal, to the model system, production of sociodemographic and economic forecasts, and 2) the flexibility of the new forecasting tool. In this paper the method is briefly described and major emphasis is given to experiments on the impact of sociodemographic changes on travel demand.

The use of cross-sectional models in travel demand forecasting involves some fundamental problems. First, it is based on the untested assumption that cross-sectionally observed variations in travel behavior can be used as valid indicators of behavioral changes over time. Second, future values of socioeconomic and demographic input variables are usually obtained using "allocation" methods, which "post-process" aggregate forecasts into "pseudo-dissaggregate" data. As such, the traditional travel demand estimation methods fail to effectively and accurately capture the internal relationships among these input variables. And third, it does not properly represent response lags involved in long-term mobility decisions (e.g., residence relocation and car ownership).

These weaknesses are recognized in the present effort and a flexible and more accurate forecasting model system is used to produce scenarios of change instead of the traditional point estimates of popular travel demand forecasting techniques. The new tool, Microanalytic Integrated Accounting System (MIDAS), consists of two components: a microsimulator of household socioeconomic and demographics, and a dynamic model system of household car ownership and mobility. Each component is made of interlinked models formulated at the household level. Replicated in the socioeconomic and demographic microsimulator, are interactions and evolutionary paths that underlie lifecycle evolution of individuals and households. Simulation units evolve from year to year, experiencing marriages, divorces, births, deaths, and so forth. Employment, income, driver's license holding, education level, and household size and composition, are among the variables that are internally generated in the simulation. Numerous parameters have been provided for modification to represent different future growth paths.

The model system has been estimated using observations from 5 waves of the Dutch National Mobility Panel data, covering a period of four years between April 1984 through April 1988. Other sources of information, external to the Panel data, were also used to estimate key parameters.

The model system is a flexible forecasting tool with which a wide range of future scenarios can be examined to answer a variety of "what-if" questions. It can replicate reality with accuracy comparable to other forecasting models and could replace the inaccurate allocation methods, often used to provide inputs for the travel demand models. However, the method is complex, poses high demands in model estimation, and requires a large amount of data.

The paper is organized as follows. In the next section, the background underlying the modeling approach here is presented together with the structure of the microsimulator. Following this, the demographic component of the microsimulator and its program elements are described in detail in Section 2. Section 3 discusses the MIDAS mobility component. Section 4 contains examples of forecasting exercises and a comparison with other forecasts. Section 5 presents a summary.

1. STRUCTURE OF MIDAS

Socioeconomic and demographic information plays an important role in the Urban Transportation Planning Process¹ (UTPP). The usual techniques providing socio-demographic input to UTPP can be summarized as follows. Forecasts on regional economic and demographic changes are obtained from agencies that routinely perform this type of forecast. While the techniques, models and procedures used to obtain input to UTPP are quite disparate, they share one common characteristic: they are not at the same level of disaggregation as travel demand models. Most agencies "transform" regional information to the district level, and then from the district level to the traffic zone level. These allocation methods do not provide the required information needed by the travel demand models. Additional detailed information is obtained using approximate post-processing procedures. Techniques of this type produce many errors throughout the process (see Tye et al., 1982, Hamburg et al., 1983, Bajpai, 1991).

An alternative method to provide disaggregate sociodemographic and economic inputs to travel demand models is using microsimulation. This is a technique which recreates, the entire lifecycle of each sample household and its household members. In this way, microsimulators are made of probabilistic models and a number of logic rules so that the transitions of individuals, from one stage in life to another, are represented as probabilistic events replicating real world transitions. When microsimulation is combined with dynamic econometric models, which reflect longitudinal changes of travel behavior, an extremely powerful and flexible forecasting system is created.

Earlier attempts to combine econometric models of travel behavior with socioeconomic forecasting have been used for a variety of planning purposes (for a review see Goulias, 1991). The uniqueness of the approach in this study is represented by the combination of a dynamic model of travel behavior with dynamic microsimulation. This combination is motivated by the following. Since simulation in general implies modelling of a process that evolves over time, dynamic disaggregate models – models that explicitly include the time dimension at the level of the most elementary unit of analysis – are the natural ingredient of the simulation. Hence, throughout the design of the tool here, dynamic models at the level of the household and the household member are used to replicate real world changes in sociodemographic characteristics and mobility. The

development and structure of the model are reported in this paper and in Goulias 1991, and Goulias and Kitamura, 1992.

The transition between household types is the fundamental element of household evolution in MIDAS. MIDAS treats the progression of a household through different household types, reflecting different lifestyles, as the basic building block of its dynamic structure. Changes in person attributes and mobility are modeled around a model of household type transition. Given a transition in the household type², new household members are generated, or existing household members are eliminated, and member characteristics are altered in MIDAS.

All pertinent person attributes are endogenously determined in the simulator, including: education, driver's license holding, employment, and personal income. All person attributes at time t are assumed to be dependent on those of time $t - 1$, and to change randomly over time (with the obvious exceptions of age, which changes deterministically, and sex, which does not change). Thus the household types and person attributes are viewed as stochastic processes in MIDAS.

The attributes of household members are used to determine household attributes, such as the number of workers, number of drivers, and total household income. Household car ownership is determined conditional on these household and person attributes and the level of car ownership in the previous period. The mobility of a household is then probabilistically determined, given the household attributes and car ownership.

2. SOCIOECONOMIC AND DEMOGRAPHIC COMPONENT

MIDAS' objective is to realistically recreate the progression of a household through life cycle stages, and simulate changes in the household members' socioeconomic attributes and demographic attributes, such as employment status and driver's license holding. Then, use these endogenously generated socioeconomic attributes to forecast household car ownership and mobility. The socio-demographic component feeds continuously information to the mobility component.

In the simulation, for example, a household member will age, form an independent household, gain employment, obtain a driver's license, marry, give birth, and so on. The size and composition of the household will change accordingly. A household member may be added to a household through a marriage, or a household may be split into two through a divorce. A child will leave his parents and form a new household. These and other changes are probabilistically generated in the simulation.

For each household, its characteristics are first read from an input file comprising records of sample households from the Dutch Mobility Panel data set. Following this, the transition between household types is simulated for each time period (one year is used as the time interval of the simulation). This process is based on a set of models that determine transition probabilities as a function of household attributes (Goulias, 1991).

Birth and Death.; The probability that a woman in a household will give birth to a child in a given year is expressed as a function of the age and employment status of the woman, and the number of children that already exist in the household. Observed frequencies are used to determine the probability that a woman in a household will give birth to a child. The event of birth is randomly generated in the simulation using household transition probabilities.

A single-person household is removed when a death takes place in the simulation. The possibility of death is also considered in connection with the transition from couple (or family) to single (or single parent). If a death does not take place in the simulation, then the transition is regarded as a result of a divorce, and the household is split into two households.

Households Formed by Children; The event of "leaving the nest," i.e., a child moving out and forming an independent household, is modeled as a function of the age, sex, and employment status of the child. Similar to the case of birth, this event is implied by household type transition. When the event of nest leaving takes place in the simulation, a new household is added to the data file with a certain probability. The evolution of this new household is simulated through the rest of the simulation period.

Employment ; The employment status of a person is determined using transition matrices developed by sex and age group. Each matrix contains the probability of change in employment from one status to another. For example, the two-by-two matrix for men in the 18 to 24 age bracket indicates that a person who is employed at time t will also be employed at time $t + 1$ with probability 0.929, and will not be employed with probability 0.071. Similarly, a person who is not employed at time t will gain employment with probability 0.160, and remain unemployed with probability 0.840, at time $t + 1$.

Employment is assumed, at this stage of MIDAS' development, to be independent from education. The assumption is based on 1) the contradictory results obtained in a preliminary analysis of causality and 2) the small sample size of the available data (see Goulias, 1991).

Income Models; Given the employment status, the personal income is determined using a set of models. Each model is formulated with a lagged dependent variable and a serially correlated error term. Thus the personal income at time t is assumed to be determined in part by the personal income at time $t - 1$. Four models are developed for the four possible combinations of the employment status at time $t - 1$ and time t : (not employed, not employed), (employed, not employed), (not employed, employed), and (employed, employed). Possible individual-specific income effects are captured by the presence of serial correlation and serve as indicators of continuity.

Driver's License and Education; The drivers license holding is determined using transition matrices similar to those for employment status. The presence of large diagonal elements in these matrices imply that license holding status is less variable than other transitions, e.g. employment. Also notable is the stability in the transition probabilities across the age groups.

The level of education is an important variable as the causal analysis has indicated. Because education is among the explanatory variables used in the MIDAS mobility component, it is necessary to determine education levels for those household members that are internally generated in the simulation process. This determination is not based on detailed modeling of education levels as it is clearly beyond the scope of this study.

For children that are generated in the simulation, their education levels are determined randomly using the distribution of education levels by sex, obtained for individuals of 18 through 28 years old in the panel data.

New Household Members; A set of personal attributes needs to be generated whenever a new household member is introduced in the simulation. As discussed earlier, when a

new person enters a household through a marriage, his/her age and education level is determined based on the existing member's age and sex. The new member's employment and income are then determined given his/her age and sex.

For a newborn member of a household, only sex is determined at the time of birth; the rest of person attributes are determined when he/she reaches the age of 18, using the probabilities of employment, license holding, and income as described above.

The person attributes of "other" household members are determined as follows. First, the age and sex of the "other" individual are randomly generated based on the age of the head of the household. Given age and sex, employment, license holding, education, and income, are randomly determined based on the observed distribution of the attributes of "other" persons, by age and sex.

Household Dissolution; A household is split into two, or eliminated from the simulation, after a divorce or other events that cause its dissolution. If children are present in the household, they are randomly assigned to the respective parents. The current version of MIDAS assumes that the mother will have the custody of a child with a probability of 75%. This, however, is an arbitrary assumption that should be improved in the future with appropriate data.

Most model parameters are estimated using subsamples from the Dutch Panel data set. A subsample of Dutch panel households is also used as initial sample in the simulation. Observed household and person attributes of 1984, 1985 and 1986 are used as initial conditions; demographic and socioeconomic attributes and mobility levels of these (and internally generated new) households are simulated year by year to 2010 in MIDAS.

3. MOBILITY COMPONENT

The MIDAS mobility component consists of a car ownership model, household motorized-trip generation models, a modal split model, car-trip distance models, and transit-trip distance models. All models are formulated for weekly totals made by individuals of 12 years and older.

Car Ownership Model; An ordered-response probit car ownership model is used to determine household car ownership in MIDAS. This model probabilistically describes the choice of an alternative from among a set of ordered discrete alternatives. A household's choice of the number of cars to own, falls in this class of choice. The model assumes the presence of a latent variable which cannot be directly measured, but is related to the observed choice—the number of cars owned in this case. Corresponding to a level of car ownership is a range of the latent variable value which is defined by unknown threshold values. Details on model estimation are found in Kitamura (1988).

Dynamic Motorized-Trip Generation Models; Weekly household motorized-trip generation models, developed using data from Waves 1,3,5,7, and 9, have been developed separately for households with cars available and those without a car available. The variables used in the models are the number of diary keepers, number of women, number of men, number of workers, a set of dummy variables to indicate income categories, multi-car ownership, number of drivers, a set of dummy variables indicating the household type, the residence area type, and a lagged dependent variable (number of trips a year ago).

Modal Split Model; Level of Service data are not available to describe trip characteristics by alternative modes that connect given origin and destination zones. Modal split models that can be developed with this limitation are not trip-interchange (post-distribution) models that focus on modal competition at the trip level. A new model structure, called binomial logistic, has been defined within this study to predict modal split. This mode choice model uses the relative frequency of trips made by a particular mode as dependent variable (see Goulias and Kitamura, 1991).

4. MIDAS FORECASTING

The tenet of MIDAS has been to extract salient longitudinal relationships in the Dutch National Mobility Panel data, and extend them into the future. The objectives of this study were to: 1) examine whether such dynamic forecasting is practical and meaningful at all; 2) test and report a comparison among MIDAS forecasts and other models' forecasts; 3) examine the short-term forecasting performance of MIDAS, and 4) illustrate its ability to study the impact of sociodemographic and economic changes on travel demand. The first, second, and third objectives have been met and related discussions can be found in Kitamura and Goulias, 1991, Goulias, 1991, Goulias and Kitamura, 1992. The fourth objective is the subject of this section.

Most model parameters are estimated using subsamples from the Dutch Panel data set. Properly weighted (see Goulias, 1991) to reflect the Dutch population observed household and person attributes of 1984, 1985 and 1986 are used as initial conditions (initial sample); demographic and socioeconomic attributes and mobility levels of these (and internally generated new) households are simulated year by year to 2010 in MIDAS.

The parameters in MIDAS can be classified into two categories. The first category contains the coefficients of the dynamic models in the mobility component, and the income models in the demographic component. These coefficients have been estimated using subsamples of the Dutch Panel data set using econometric methods, and embedded in MIDAS. The second category contains parameters of the demographic component, most of which are transition probabilities.

Most of the parameters in the demographic component are treated as input data for scenario building. The MIDAS computer code contains 16 sets of parameters representing probabilities of various demographic and socioeconomic changes. Their values have been estimated using the Dutch Panel data set. These parameters can be modified to represent a particular scenario of interest (e.g., an increase in women's labor force participation) or incorporate external information. These 16 sets of parameters are: 1) The probability that a woman in a household will give birth in a given year, by employment, number of children in the household, and age of the woman; 2) the probability that a child in a household will leave the household in a given year, by age, sex, and employment; 3) probability distribution of the age category of a male adult in a household given his spouses age category; 4) probability distribution of the age category of a female adult in a household given her spouses age category; 5) probability of employment by age and sex (for new household members); 6) probability of holding a driver's license, by age and sex (for new household members); 7) probability distribution of the education category of a male adult, given that of the female adult in a household (for new household members); 8) probability distribution of the education category of a female adult, given that of the male adult in a household (for new household members); 9) probability distribution of the number of children in a household, by the age of the female adult; 10) probability distribution of the age of the youngest child by the age of the female adult; 11) joint distribution of the age and sex of the head by household type; 12)

probability that an "other" household member is employed, by his/her age; 13) probability distribution of the education category of an "other" member; 14) transition probability of employment by age and sex; 15) transition probability of license holdings by age and sex; and 16) probability of death in a given year, by age and sex.

In addition, the following input parameters can be used for modification of MIDAS default settings (their default values are shown in parenthesis): 1) RINF modifies annual growth rate in personal income (1.0); 2) BFCTR modifies birth probabilities (0.0); 3) MEFCTR and FEFCTR modify male and female employment transition probabilities, respectively (0.0); 4) MLFCTR and FLFCTR modify male and female license holding transition probabilities, respectively (0.0); 5) SGFCTR modifies single-to-single household type transition probability (0.0); 6) CPFCTR modifies couple-to-couple household type transition probability (0.0), 7) FMFCTR modifies family-to-family household type transition probability (0.0), and 8) SPFCTR modifies single parent-to-single parent household type transition probability (0.0).

Manipulation of the MIDAS parameters that have been estimated using the Dutch Panel data is used to control income growth and represent income growth scenarios. In another simulation the array of birth factors is used to inflate fertility rates and produce the consequent increased fertility growth scenario. Virtually infinite scenarios can be created by manipulating the MIDAS modifiers.

The results of a "baseline" MIDAS run are first presented (hereafter called the middle scenario). The baseline run assumes an income growth rate similar to the Central Planning Bureau's (CPB) "referentie" scenario, assumed baseline scenario of growth for the Netherlands. These middle scenario results have been compared and found very similar to observed Dutch National mobility statistics, car ownership forecasts by cohort models, and mobility forecasts by a cross sectional national model (see Kitamura and Goulias, 1991).

The MIDAS baseline forecast represents an income growth of 57% by year 2010. The results are presented in Table 1 for year 1986 (base year), 1995, 2000, 2005 and 2010. All MIDAS results presented in this section are averages of five simulation runs repeated for each simulation case using different seeds for random number generation.

Simulation results are given for household size, labor force participation, license holding, automobile ownership, and for five mobility measures: number of motorized trips, number of car trips, and number of transit trips. All mobility measures are weekly totals including trips made on weekend. Nationwide figures are developed by multiplying national population estimates (used in the CPB baseline scenario) to the per-capita figures generated by MIDAS.

In presenting these absolute values of mobility measures, it is noted that the MIDAS mobility forecasts are based on the mobility component estimated using the Dutch Panel data together with base-year trip rates reported in the 1986 Dutch Panel survey. It has been reported that reported trip rates in the Dutch Panel data are subject to biases due to under-reporting of trips. Therefore the absolute mobility forecasts reported in this section must be carefully interpreted, and more emphasis should be placed on relative changes in their values rather than their absolute values.

The results show a rapid decrease in household size, gradual increase and then decline in labor force participation, and increases in the driver population and household car ownership. All mobility figures show substantial increases.

Household size declines from the initial 2.64 in 1986 to 2.38 in year 2000, and 1.94 in year 2010. Central Bureau of Statistics (CBS) statistics indicate that the average number of persons per household declined from 2.95 in 1975 to 2.54 in 1985 (CBS, 1988). This represents a decline of over 0.4 person per household in a decade, or 0.041

Table 1
Comparison of Three Income Growth Scenarios

	Base Year 1986	MIDAS Forecasts for 2010 by Income Growth Rate					
		Low		Middle		High	
Population (x 10 ⁶) ⁺	14.5	15.1		15.1		15.1	
Population, ≥ 12 Years Old (x 10 ⁶) ⁺⁺	12.3	13.0		13.0		13.0	
Household Size	2.64	1.96	-26%	1.94	-27%	1.96	-26%
Labor Force Participation*	42.7%	41.3%		41.2%		41.1%	
Average Income per Employed Person	100	125		157		198	
Number of Licensed Drivers (x 10 ⁶) ^{**}	7.19	10.22	42%	10.04	40%	10.06	40%
Percent of Licensed Drivers	49.6%	67.7%		66.5%		66.6%	
Number of Automobiles (x 10 ⁶) ^{**}	4.50	6.80	51%	7.10	58%	7.40	64%
Automobiles per Person	0.31	0.45		0.47		0.49	
Automobiles per Household	0.82	0.88		0.90		0.96	
Automobiles per Driver	0.62	0.67		0.70		0.73	
Number of Motorized Trips per Week							
Per Person	9.35	12.51	34%	12.86	38%	13.38	43%
National Total (x 10 ⁶) ^{**}	115.0	162.6	41%	167.2	45%	173.9	51%
Number of Car Trips per Week							
Per Person	8.28	11.21	35%	11.47	39%	11.99	45%
National Total (x 10 ⁶) ^{**}	101.8	145.7	43%	149.1	46%	155.9	53%
Number of Transit Trips per Week							
Per Person	1.07	1.31	22%	1.39	30%	1.38	29%
National Total (x 10 ⁶) ^{**}	13.2	17.0	29%	18.1	37%	18.0	36%

⁺CPB scenario.

⁺⁺Van den Broecke Social Research (1987, Deel I, p.3, Deel IV, Table 1).
The 2010 figure adjusted to agree the CPB forecast.

*Among individuals of 15 years old and over (CPB), or 18 years old and over (MIDAS).

**MIDAS forecasts are expanded using the national population (of individuals of 12 years old and over for mobility measures).

person per year. The above decrease forecast by MIDAS, i.e., 0.44 person in the first 15 years and 0.26 in the following 10 years, may in fact accurately reflect the observed trend. The continuing decline in the twenty-first century depicted by MIDAS may reflect the aging of the population. Should there be reasons to believe that this trend may change in the future, then MIDAS is capable of generating forecasts reflecting such changes. The results from two additional simulation runs for income growth one for recession (low) and the other for an upswing (high growth) scenario are also reported in Table 1. The variable RINF was set to suitable values to obtain the desired growths.

Evidence from the literature and a preliminary analysis (see Goulias, 1991) suggest that decision making regarding the number of children to have, the labor force participation of the household members, the education of the household members, and the resulting household income is particularly complex.

A unique opportunity, to examine the effect of these complex relationships on travel demand, is offered when a microsimulator like MIDAS is available. In this section an example of the use of the MIDAS modification factors is given. The increased fertility scenario is produced by modifying an array associated with the probabilities of birth. The forecasts obtained with the default values and the forecasts based on "inflated" fertility are presented in Table 2. In comparing these results, it should be noted that the increased fertility scenario resembles a possible situation where a large number of immigrants moves into the Netherlands during a period of economic contraction resembling the recession scenario.

An important difference between the increased fertility scenario and the recession scenario is the difference in household size. As expected household size is not declining as rapidly in the increased fertility scenario (2.15) as in the recession scenario (1.96). This slower decline in household size – due to an increase in the number of children in the household – affects most of the mobility measures substantially. The car ownership is increasing at much slower rates in the increased fertility scenario than in the recession scenario. This is due to two factors, the decline in labor force participation and the decline in the average age of the sample produced under the increased fertility scenario. Overall the increased fertility scenario has produced mobility measures of approximately 10% lower level than the recession scenario. It is interesting to note that increased fertility does not affect the number of transit trips.

5. SUMMARY AND CONCLUSIONS

This study represents an entirely new approach to travel demand forecasting. Unlike the conventional approach of taking externally produced aggregate demographic and socio-economic forecasts and using them as input to a cross-sectionally estimated model system, the dynamic microsimulation system of this study, MIDAS, generates demographic and socio-economic, as well as car ownership and mobility forecasts internally through microsimulation. A system of dynamic models, estimated using the Dutch National Mobility Panel data set is applied in the simulation.

The study is based on the recognition that no external demographic and socio-economic forecasts are furnished at levels that meet the data requirements of sophisticated discrete choice models currently used in transportation planning. Specifically, no external forecasts are produced to provide a multivariate distribution of the array of explanatory variables typically used in travel choice models, at the levels where these models are formulated, i.e., households or individuals .

The use of microsimulation is motivated by its flexibility and its ability to forecast direct and indirect effects of the simulated policies on the system analyzed.

Table 2
Comparison of Default and Increased Fertility Scenarios

	Base Year 1986	MIDAS Recession Forecasts for 2010			
		Default Fertility		Increased Fertility	
Population (x 10 ⁶) ⁺	14.5	15.1		15.1	
Population, ≥ 12 Years Old (x 10 ⁶) ⁺⁺	12.3	13.0		13.0	
Household Size	2.64	1.96	-26%	2.15	-19%
Labor Force Participation*	42.7%	41.3%		36.8%	
Average Income per Employed Person	100	125		122	
Number of Licensed Drivers (x 10 ⁶) ^{**}	7.19	10.22	42%	9.53	32%
Percent of Licensed Drivers	49.6%	67.7%		63.1%	
Number of Automobiles (x 10 ⁶) ^{**}	4.50	6.80	51%	6.19	38%
Automobiles per Person	0.31	0.45		0.41	
Automobiles per Household	0.81	0.88		0.88	
Automobiles per Driver	0.62	0.67		0.65	
Number of Motorized Trips per Week					
Per Person	9.35	12.51	34%	11.65	25%
National Total (x 10 ⁶) ^{**}	115.0	162.6	41%	152.6	33%
Number of Car Trips per Week					
Per Person	8.28	11.21	35%	10.35	25%
National Total (x 10 ⁶) ^{**}	101.8	145.7	43%	134.6	32%
Number of Transit Trips per Week					
Per Person	1.07	1.31	22%	1.30	21%
National Total (x 10 ⁶) ^{**}	13.2	17.0	29%	16.9	28%

⁺CPB scenario.

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The 2010 figure adjusted to agree the CPB forecast.

*Among individuals of 15 years old and over (CPB), or 18 years old and over (MIDAS).

**MIDAS forecasts are expanded using the national population (of individuals of 12 years old and over for mobility measures).

Microsimulation fills the gap in forecasting the input to travel demand models and provides the framework to design new dynamic forecasting tools. The forecasting exercise reported in this paper provides evidence that a dynamic microsimulator is a tool which can be used to differentiate and exemplify the effects of policy actions on sociodemographic and economic factors which in turn affect travel behavior.

Therefore, microsimulation-based systems are suitable for the design of flexible forecasting travel demand tools. A variety of policy options can be studied by performing simulations based on different sets of input parameters and a relatively small database. A model system of this type, however, is complex, the development of a dynamic demographic microsimulation model requires a large amount of data, and readily available population statistics may not be useful in developing a dynamic demographic microsimulation model.

NOTES

1 The process widely known as the four stage procedure (trip generation, trip distribution, mode-choice and assignment) requires the provision of input variables such as population, income, employment, and car ownership.

2 Five household types are used in MIDAS: a) Single-person households (Singles); b) Households of a man-woman couple (Couples); c) Nuclear family households (Families); d) Single-parent households (Single Parents); and e) Other households (Others). This classification is based on the belief that the composition of adult members of a household is closely associated with its travel behavior.

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